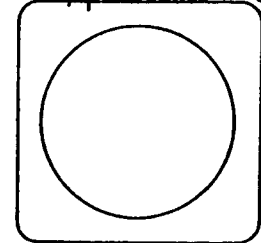


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EARTH SATELLITE CORPORATION
(EarthSat)



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TELEPHONE: (202) 223-8100 TELEEX: EARTHSAT64449

May 9, 1973

ERTS Program Manager
Code ER
NASA Headquarters
Washington, D.C. 20546

Original photography may be purchased from
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

RE: Contract No. NAS5-21795 GFSC ID ST 355

Gentlemen:

The Indiana Geological Survey and Earth Satellite Corporation (EarthSat) are pleased to submit a progress report for the period of March 1, 1973 to May 1, 1973. To facilitate for review by NASA a consistent summary format has been adopted for month to month reporting.

A. TITLE: Study of Application of ERTS-A Imagery to Fracture-Related Mine Safety Hazards in the Coal Mining Industry.

B. PRINCIPAL INVESTIGATOR: Dr. Charles E. Wier (SR #325)

C. CO-PRINCIPAL INVESTIGATOR: Dr. Frank J. Wobber

D. PRINCIPAL CONTRIBUTORS: Dr. Charles E. Wier
Mr. Orville R. Russell
Mr. Roger V. Amato
Dr. Frank J. Wobber

E. SUMMARY OF ACCOMPLISHMENTS:

- U-2 70mm multispectral and RC-8 color infrared photography flown at 65,000' by NASA in January on EarthSat-designated flight lines was received during this reporting period. Analysis of these data is in progress.
- C-130 RC-8 color, color infrared, 70mm multispectral photography and 8-14mm thermal imagery acquired at 15,000' during a March 1973 NASA underflight has been received. A preliminary evaluation of these data indicates that the photography is very useful for collection of fracture information and for mined lands investigations. The investigators have

E73-10681) STUDY OF APPLICATION OF
ERTS-A IMAGERY TO FRACTURE RELATED MINE
SAFETY HAZARDS IN THE COAL MINING
INDUSTRY Progress Report, 1 (Earth
Satellite Corp.) 15 p HC \$3.00 CSCL 08I

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- ° determined that the optimum time of year for fracture mapping in this part of the country is March through April because of the large amount of bare ground exposed by spring plowing. The thermal imagery quality was degraded by static discharge marks. No multispectral scanner data was received.
- ° A three day field trip was made to the test area in April (see attached report) for light aircraft and ground observations. The physical manifestation of mapped lineaments were noted and evidence of mine subsidence and mined land disturbances were examined.
- ° Mine operators were contacted concerning roof fall problems, fracture conditions in mines and the potential application of hazards prediction maps. Detailed fracture mapping is continuing on the test mine sites including the Thunderbird Mine, the Kings Station Mine, the Mecca Mine, and a new Amax Mine currently under development.
- ° A 1:250,000 scale Mined Lands Inventory Map (see enclosure) of a portion of southwest Indiana, prepared on an ERTS imagery photo-base was issued as a prototype for a National Mined Lands Inventory. On the basis of this work, EarthSat has been asked to testify before the Senate Aeronautical and Space Sciences Committee concerning the applications of remote sensing for mined land investigations.
- ° Selected ERTS imagery of the entire test area has been enlarged to 1:250,000 scale for use as a mapping base and all fractures and known structural data have been posted. A mine roof hazards map will be generated from this data.

F. SIGNIFICANT RESULTS

The 70mm black and white infrared photography acquired in March 1973 at a approximate scale of 1:115,000 permits the identification of areas of mine subsidence not readily evident on other films. This is largely due to the high contrast rendition of water and land by this film and the excessive surface moisture conditions prevalent in the area at the time of photography. Subsided areas consist of shallow depressions which have impounded water. Patterns with a regularity indicative of the room and pillar configuration used in subsurface coal mining are evident.

H. RECOMMENDATIONS FOR TECHNICAL CHANGES:

Considerable interest in ERTS and aircraft remote sensing has been generated in state offices following release of the mined lands inventory maps. Several mined land area problems require study by state agencies. These include a refuse pile and slurry pond inventory for reclamation assessment, identification of areas of mined land subsidence, and a comprehensive analysis of the capabilities of ERTS-1 imagery for detecting mined area changes. The latter should include status of vegetal cover and

May 9, 1973

changes in areas of disturbance. A letter proposal has been submitted to NASA for the conduct of a refuse pile-slurry pond inventory. Additional proposals for the other above mentioned avenues of investigation will be forthcoming. The investigators feel that such data will have far reaching benefits both to Indiana and to NASA as important mined land legislation is currently being developed in Congress.

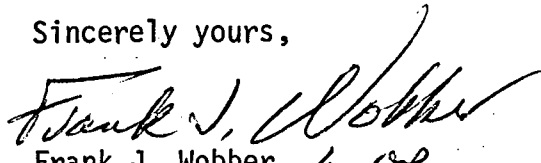
I. CHANGES TO STANDING ORDER FORMS

All change requests have been made on the standing order.

J. OVERVIEW OF INVESTIGATION

During this reporting period, NASA has delivered substantial quantities of U-2 and C-130 underflight data acquired in January and March 1973. This imagery contains considerable information concerning fracture traces and mined land conditions in the project area and is a useful complement to ERTS imagery. However, as more underflight imagery has been delivered than was originally anticipated, greater costs for analysis and integration of this data have arisen. The correlation of remote sensor-derived fracture data with past mining fatalities is continuing. Photobase maps of ERTS-1 imagery enlarged to a scale of 1:250,000 have been made for the southern portion of the test area and fractures have been plotted. Transfer is continuing of fractures mapped on the 1971 high altitude color infrared aerial photography to a 1:250,000 stable base map for purposes of ease of reference, data consolidation, and validation of fractures.

Sincerely yours,


Frank J. Wobber
Director
Geosciences and Environmental
Applications Division

FJW/rlt
ATTACHMENT

4

PROGRESS REPORT SUMMARY

Reporting Period

March 1, 1973 - April 30, 1973

Category: 3 - Mineral Resources, Geological Structure and Land-form Surveys

Sub-Category: 1 - Mine Safety, Hazard Survey and Environment (Mined Lands) Assessment

Title: Study of Application of ERTS-A Imagery to Fracture-Related Mine Safety Hazards in the Coal Mining Industry

Principal Investigator: Dr. Charles Wier

Co-Investigator: Dr. Frank J. Wobber

SUMMARY:

A Mined Lands Inventory Map at 1:250,000 scale of a portion of the Indiana coal field was issued as a prototype for a national mined lands survey.

Field investigations were made to examine in greater detail the character of fracture manifestation in glacial drift covered areas. Discussions with mine operators were commenced concerning roof fall problems and the potential application of mining hazards prediction maps.

Black and white infrared photography taken in March, revealed evidence of mine subsidence not obvious on other films. Color IR, also taken in March, shows an abundance of fractures and lineaments and the investigators have determined that March through April is the optimum time of the year for seeing such features. An ERTS image base map has been completed for the entire test area and all fracture data have been plotted.

SUMMARY OF OBSERVATIONS OF INDIANA

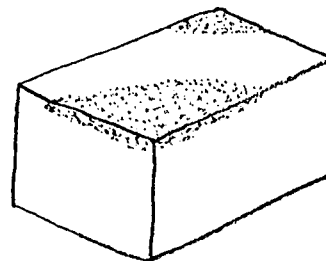
FIELD TRIP - APRIL 16, 17, 18, 1973

I. Field (Ground Observations)

A. Fracture Investigation:

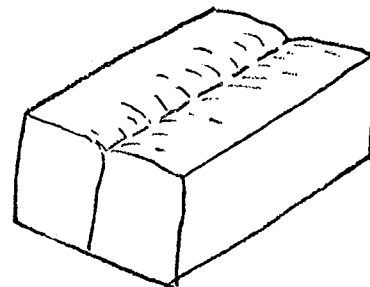
(1) Soil Tone Types -

- Checked several plowed fields which displayed tonal alignment on the Color IR imagery
- Observed that most of the soil tone linear patterns are sedimentation - related, rather than structural breaks. The light colored tones appear to be lake bed clays while the dark tones are organic-rich clays of a probable swamp-type depositional environment.
- Samples were taken of the different soil tones types.



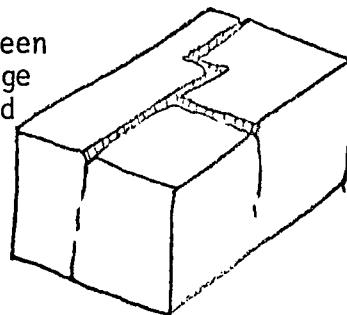
(2) Topographic Depression Types -

- Checked several plowed and unplowed fields for evidence of linear features seen on the Color IR imagery



(3) Aligned Stream Segment Types -

- Noted that most of these linear features were expressed as very subtle topographic depressions (linear dry valleys and gullies), somewhat analogous to the Mollard theory of ground-water movement and soil settling along fractures.
- Checked several straight stream segment in glacial drift covered areas to determine if they were naturally aligned or if they had been straightened by man for irrigation or drainage purposes. The stream segments checked showed no evidence of man-made alteration.



B. Gob Pile Investigation:

Visits were made to several large unreclaimed gob piles and characteristics such as vegetal type and growth, erosion and leaching, abundance of sulphide-bearing materials, abundance of shale and clay vs. coal, and state of oxidation and degree (if any) of burning. The older piles which had been burned (a practice now banned) were the most oxidized and supported more vegetal growth. Burned gob is widely used as base material in local road construction. Several large gob pile reclamation projects were noted including the levelling of the piles and slurry ponds at the Thunderbird mine.

C. Mine Subsidence Investigation:

Several areas of mine subsidence identified from aerial photography were studied. One large area along Busseron Creek near the town of Sullivan was unknown to the State. The presence of old mine workings, relict gob piles, scarps, submerged vegetation such as sunken trees, etc. helped verify that the low-lying, roughly rectangular shaped and often water-filled areas are the product of mine subsidence. Subsidence appears to occur predominantly in low-lying, wet creek and river bottom lands which may tend to sag and collapse more readily than the uplands as a result of water saturation, leaching and accentuated zones of weakness.

II. Light Aircraft Observations [REDACTED]

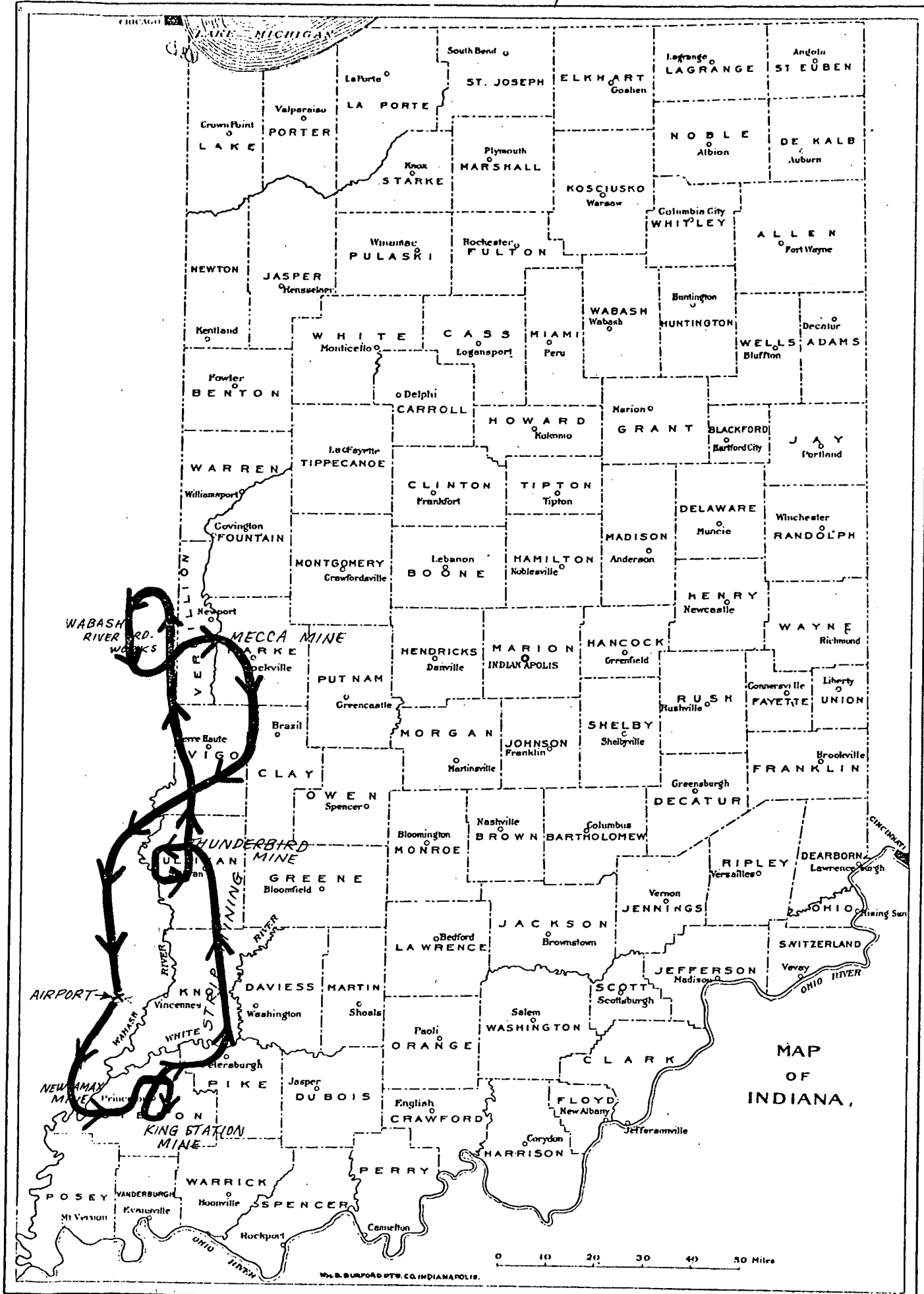
A three-hour long light aircraft underflight was made on April 17th. beginning at St. Francisville, Illinois and covering most of the test area as well as individual test sites. Detailing (circling at

lower altitudes) was done over the test mine sites including the new Amax mine under development along the Wabash River, the Kings Station coal mine at Princeton, the Thunderbird mine at Shelburn, the Mecca mine at Mecca and over an area northwest of Terre Haute where a prominent series of linear patterns had been observed on the Corn Blight Imagery. Observations included the recognition of various types of field plowing practices which might be misconstrued as possible fractures, the validation of several suspected linear features on the interpreted imagery as definite fracture traces, the recognition of the "patchy" soil tone changes as being of probably glacial-lacustrine origin, the noting and photographing of fractures in the test mine sites, the recognition of surface expressions of mine subsidence, and the various extents of gob pile overgrowth, reclamation, and use as road base material.

III. Visit To Kings Station Mine - April 18, 1973

Spoke with Mr. Harry Lovell, superintendent of the mine, on some of the various mining practices and problems of the Kings Mine and about coal mining in general. Types of roof fall problems and some of the areas where this is a serious problem in the mine were discussed and the current mine map was studied. Mr. Lovell noted that most of the roof-falls occur in linear patterns along drifts and passageways and that sections 22-24 and sections 18-19 were where they were experiencing most of their roof trouble. He indicated that in his opinion the majority of the problems of roof fall were associated with lithology changes (thin siltstone-shale laminations). However, although not specifically stated, his comments could be interpreted that in places fracturing may have contributed to roof problems. Lovell also commented that there was no relationship between recent drift direction and mining problems, however, former areas or irregular mining may indicate roof problems.

He also discussed some of the corrective measures they were using including roof bolt sizes, types, and spacings, and steel arching and other supports.



General flight route of Light aircraft underflight, April 17, 1973.

TASK STATUS REPORT

Contract # NAS5-21795



= Completed Tasks

TASK	STATUS	COMMENTS
PHASE II FIRST LOOK ANALYSIS		
1.0 RECONNAIS- SANCE ANALY- SIS OF ERTS-1 IMAGERY		
1.1 PREPARE ERTS BASE MAP	COMPLETE	An ERTS Imagery photo-base map has been prepared at a scale of 1:250,000 for the area corresponding to the Vincennes, Indiana 1:250,000 scale topographic sheet. A National Mined Lands map phototype was prepared using the base map. Others maps are being prepared as suitable (cloud free) imagery becomes available.
1.2 ANNOTATE BASE MAP WITH HAZARDS DATA	UNDERWAY	Various data relating to coal mining hazards are being compiled on a base map. These data include incidents of rooffalls resulting in miner deaths, and evidence of changing mine drifts indicative of weak roof.
1.3 PRELIMINARY ERTS-1 IMAGERY ANALYSIS	COMPLETE	ERTS-1 imagery has been analyzed for fracture lineaments. This will be a continuing effort. A fracture validation system (see Task 2.0, continuing data analysis) has been adopted.
1.4 RANK ERTS-1 SPECTRAL BANDS	COMPLETE	The utility of individual spectral bands for mine hazards investigations has been established by EarthSat based on imagery during the summer season and good fall coverage. This assessment will continue throughout the year. NOTE: Based on imagery to date, MSS Bands 5 and 7 appear to be most useful for fracture discrimination purposes.

TASK	STATUS	COMMENTS	
PHASE II (Cont'd)			
2.0	PRELIMINARY COMPARISON OF ERTS-1 LINEAMENTS AND KNOWN HAZARDS DATA	COMPLETE	Within the Indiana coal field the greater quantity of lineaments identified on ERTS imagery occur north of Terre Haute. A test site has been selected for special study in Parke County where underground mining is present. King State Mine was studied.
3.0	INITIAL TESTING OF FRACTURE ANALYSIS TECHNIQUES		
3.1	MANUAL ANALYSIS	COMPLETE	The various standard manual analysis techniques apply equally well to ERTS imagery as to aerial photography. Scan line traces tend to obscure lineaments parallel to traces. Both ERTS-1 imagery and small scale photography were applied to mapping geological lineaments.
3.2	FILM SANDWICH	UNDERWAY	Standard film sandwich edge enhancement techniques have not been used extensively due to quality of ERTS negatives and due to availability of electro-optical instrumentation which accomplishes same results.
3.3	COMPUTER- ASSISTED	UNDERWAY	Fracture trace angle measurement and rosette plotting by computer are being programmed.
3.4	OPTICAL/ ELECTRO- OPTICAL	COMPLETE	Additive color and density slicing techniques are being used as required.

TASK	STATUS	COMMENTS
PHASE II (Cont'd.)		
4.0	GENERAL ANALYSIS OF NASA AIRCRAFT IMAGERY	COMPLETE First analysis of the 1:120,000 scale color infrared (corn blight) photography as a complement to ERTS-1 imagery has been completed. Fracture lineaments were identified in selected study areas using a validation system.
5.0	TEST ERTS-1/ AIRCRAFT IMAGERY TO PROBLEMS OF MINING AND ENVIRONMENT	COMPLETE Mined land (environmental) information is available from ERTS imagery. The extent of surface mining activity, resultant water bodies, large refuse piles and slurry ponds are being identified. An updated inventory of mined lands was completed by IGS and EarthSat.
6.0	PREPARE AND SUBMIT DATA ANALYSIS PLAN	COMPLETE Submitted and approved.

TASK		STATUS	COMMENTS
PHASE III CONTINUING DATA ANALYSIS			
1.0	CONTINUE APPLICATION OF ERTS-1/ AIRCRAFT OF MINING-ENVIRONMENT STUDIES	COMPLETE	National prototype for mined land inventory has been prepared (Vincennes Quadrangle, Indiana).
2.0	ESTABLISH FRACTURE VALIDATION SYSTEM	COMPLETE	A preliminary validation system has been prepared by EarthSat. Following testing, it will be revised and finalized.
3.0	CONDUCT DETAILED ANALYSIS OF ERT-1/ AERIAL PHOTOGRAPHY	UNDERWAY	High altitude (1:120,000) scale aerial photography and all ERTS-imagery is now being analyzed. Reconnaissance analysis of data from NASA aircraft mission No. 210 and 230, plus U-2 Flight No. 73-008 is continuing.
4.0	CONSOLIDATE FRACTURE DATA	UNDERWAY	Plans to consolidate fracture data (reduce overlays, etc. to common base) have been made.
5.0	COMPARE UNDERGROUND SURFACE MINE ACCIDENT DATA TO FRACTURE ZONES	UNDERWAY	Attention is being given to the Thunderbird Mine in Sullivan County where considerable fault and roof fall data has been assembled by the Principal Investigator.
6.0	DELIMIT HAZARDOUS ZONES IN ACTIVE/ ANTICIPATED COAL MINING AREAS	UNDERWAY	Several potentially hazardous areas have been predicted in the King Stations Mine preliminary to a mine visit.

TASK		STATUS	COMMENTS
PHASE III (Cont'd)			
6.1	ESTABLISH CRITERIA FOR DETERMINING HAZARDOUS ZONES	UNDERWAY	Preliminary, areas of numerous joint intersections, high density fractures and isolation of "blocks" by fractures are among the criteria being studied.
6.2	PREPARE MAP OF EVALUATION OF HAZARDOUS ZONES	UNDERWAY	Suitable map scale has been selected.
7.0	DEVELOP PROTOTYPE MINE SAFETY INFORMATION NETWORK		
7.1	VISIT MINE OPERATORS DISCUSS APPLICATIONS OF HAZARDS DATA	UNDERWAY	The King Station Mine was visited and roof fall problems discussed.
7.2	ESTABLISH FORMAT FOR MINE SAFETY DATA DISTRIBUTION		
7.3	DISTRIBUTE MINE HAZARDS MAP		

TASK		STATUS	COMMENTS
PHASE III (Cont'd.)			
8.0	PREPARE FINAL REPORT AND TECHNICAL BRIEFS	UNDERWAY	Final report being prepared as study proceeds. Revised final report outline completed.
9.0	PREPARE COAL INDUSTRY TECHNICAL SEMINAR PROGRAM	UNDERWAY	Early and very preliminary contacts made with industry representation.